Introduction

- GSI BMPs
- Hydrologic Modeling
- Modeling Example
- Hydrostats Example
- Pre-sized Method & Calculator

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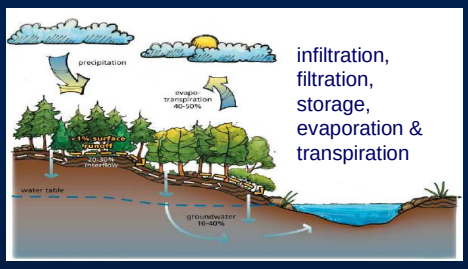
GSI BMPs

Mimic Pre-development Hydrologic Processes



infiltration, filtration, storage, evaporation & transpiration

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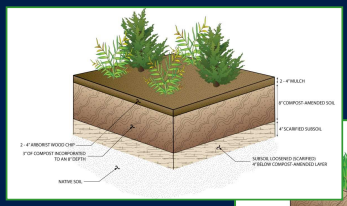
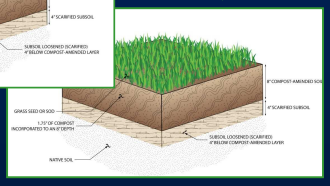
GSI BMPs

Post Construction Soil Quality and Depth



Landscape

Turf



Required for all disturbed pervious areas

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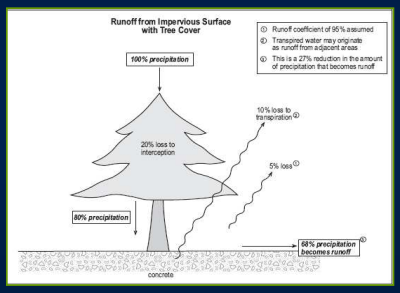
GSI BMPs

Retained and Planted Trees



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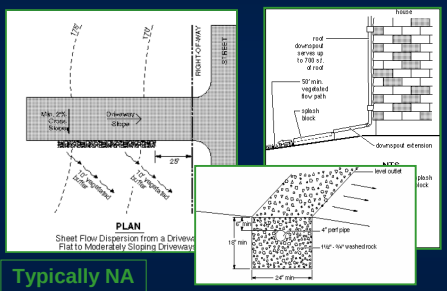
GSI BMPs

Dispersion

Downspout & Sheet flow



Typically NA in City

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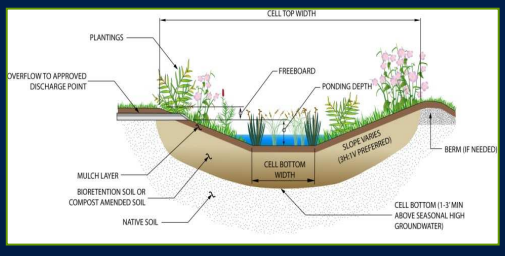
GSI BMPs

Bioretention



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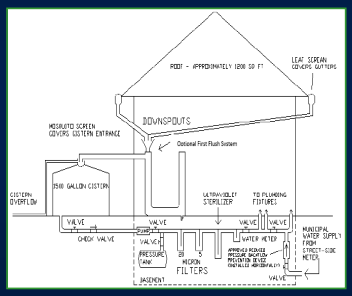
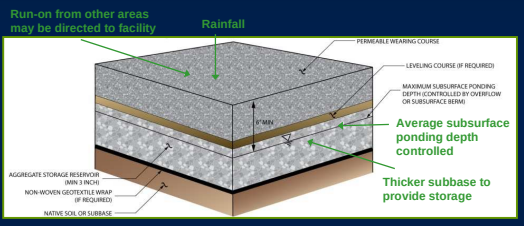
GSI BMPs

Rainwater Harvesting



GSI BMPs

Permeable Pavement Facility

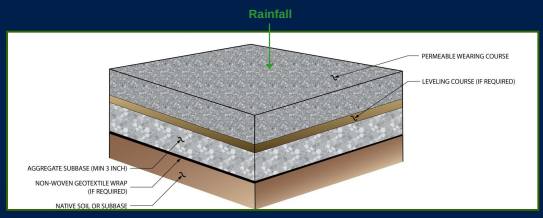


GSI BMPs

Green Roofs

GSI BMPs

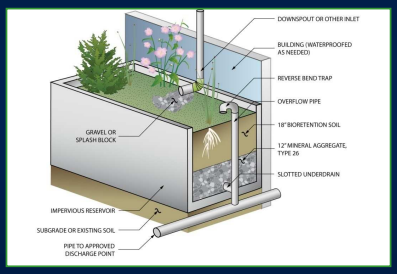
Permeable Pavement Surfaces



Not considered infiltration facility → restrictions and setbacks do not apply

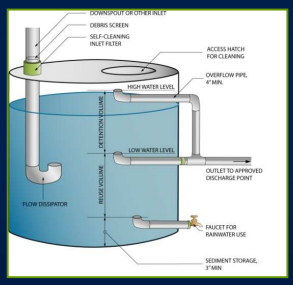
GSI BMPs

Bioretention with Underdrain



GSI BMPs

Detention Cistern with Harvesting Capacity



GSI for SFR Only

GSI BMPs

Traditional Infiltration BMPs

Capability of GSI BMPs

BMP	Flow Control	Treatment *
Soil Amendment	required	
Trees	X	
Dispersion	X	
Bioretention	X	X
Rainwater Harvesting	X	
Permeable Pavement	X	X
Green Roofs	X	
Bioretention (w/ underdrains)	X (peak)	X

* Infiltrating through soil meeting Ecology treatment requirements

Seattle Standards

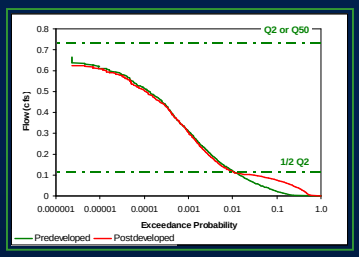
- GSI required to MEF → Under Development
- Pre-developed Pasture
  - Match durations/flows to pasture condition ($^1/_2$ 2-yr to 2-yr)
- Pre-developed Forest
  - Match durations/flows to forest condition ($^1/_2$ 2-yr to 50-yr)
- Peak Flow Control
  - Maximum 2- and 25-year flows
- Water Quality Treatment (Infiltration BMPs)
  - Infiltrate 91 % through soil meeting treatment requirements

BASED ON CONTINUOUS MODELING

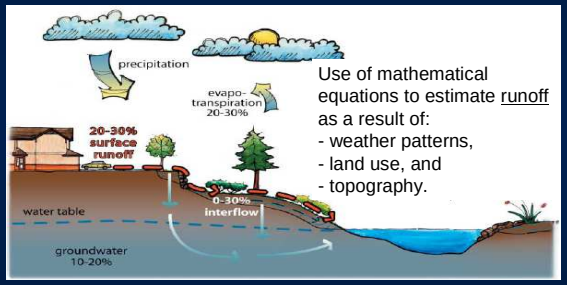
Pasture Duration Std

Match post development flows & durations from ½ 2-year to 2-year to pre-developed pasture condition

Flow Duration Plot →



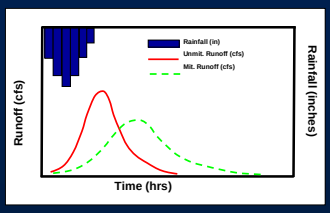
Hydrologic Modeling



Use of mathematical equations to estimate runoff as a result of:
- weather patterns,
- land use, and
- topography.

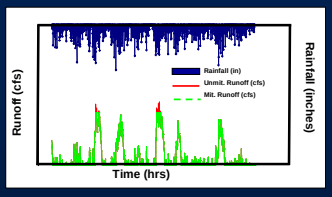
Single-Event Methods

- Single storm event (typically 24-hours)
- Simulate corresponding runoff (peak flow)
- Ex. SCS, SBUH, StormShed, xp-SWMM, HEC-HMS



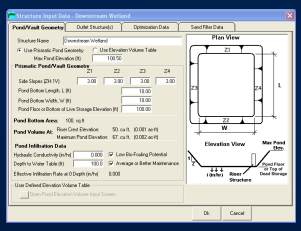
Continuous Models

- Long-term input rainfall and evaporation
- Simulate long-term runoff, peak flows, and duration
- Ex. HSPF, WWHM, MGS Flood



Continuous Models

- Available Models
  - Western WA Hydrology Model (WWHM)
  - MGS Flood
    (Based on HSPF)
- HydroStats
- Pre-Sized Method



Model Status

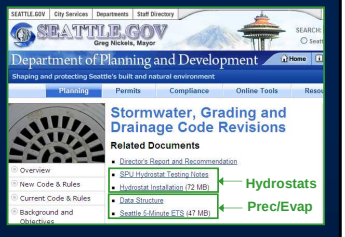
Issue	WWHM3Pro	MGSFlood
Cost	**Free**	**~$1,500**
158-year Prec/Evap	**Import**	**Built-In**
Bioretention Module	**Complete**	**by Jan 2010**
Permeable Pvmnt Module	**Use Trench**	**by Jan 2010**
Green Roof Module	**Complete**	**by Jan 2010**
Flow Frequency Correct for Infiltration BMPs	**No**	**Yes**

Model Inputs

- Rainfall Record (5-min)
- Evaporation Record (daily)
- Impervious Area(s)
  - Slope
- Pervious Area(s)
  - Vegetation
  - Soil type (A, B, C/D)
  - Slope
- BMP Configurations
  - Routing (stage-storage-discharge table)

Seattle Requirements

- Rainfall / Evaporation Record:
  MGS 158-year extended series
- 5 minute time step
- HydroStats Post Processor
- Modeling methods for BMPs in DR



Bioretention Model Example

- Site in Seattle
- 5 minute time-step
- Soil is Till (0.5 inch/hour design infilt. rate)
- Bioretention cell (12” ponding, no underdrain)
- Receiving runoff from 5,000 sf of imp. area
- Size area to achieve pasture standard
- Using bioretention module in WWHM3Pro

Modeling Requirements

Variable	Assumption
Precipitation Series	Seattle 158-year, 5-minute series.
Time Step	5-minutes.
Inflows to Facility	Surface flow and interflow from drainage area routed to facility.
Precipitation and Evaporation Applied	Yes. If model does not apply precipitation and evaporation to facility, include the facility area in the basin area (note that this will significantly underestimate the evaporation of ponded water).
Bioretention Soil Infiltration Rate	For imported City of Seattle bioretention soil per specification 7-21 see Table 4.13. For compost amended native soil, rate shall be equal to the native soil design infiltration rate.
Bioretention Soil Porosity	For imported City of Seattle bioretention soil per specification 7-21, porosity is 40 percent. For compost amended native soil, porosity can be assumed to be 30 percent.
Bioretention Soil Depth	Minimum of 12 inches for flow control. Minimum of 18 inches for water quality treatment
Native Soil Design Infiltration Rate	Measured infiltration rate with correction factor applied, if applicable (Section 4.3.3, Appendix E). If imported bioretention soil is used, a correction factor for plugging is not required.
Infiltration Across Wetted Surface Area	Yes if side slopes are 3H:1V or flatter. For steeper side slopes, only infiltration across the bottom area is modeled.
Underdrain (optional)	If underdrain is placed at bottom extent of the bioretention soil layer, all water which enters the facility must be routed through the underdrain. If there is no liner or impermeable layer and the underdrain is elevated within the bioretention soil, water stored in the bioretention soil below the underdrain may be allowed to infiltrate.
Outlet Structure	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over riser edge or notch. Note that total facility depth (including freeboard) must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge.

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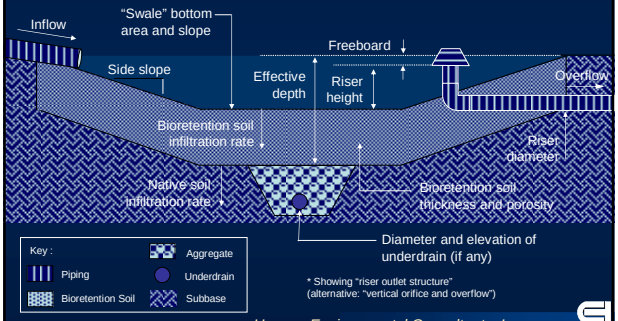
Bioret. Representation



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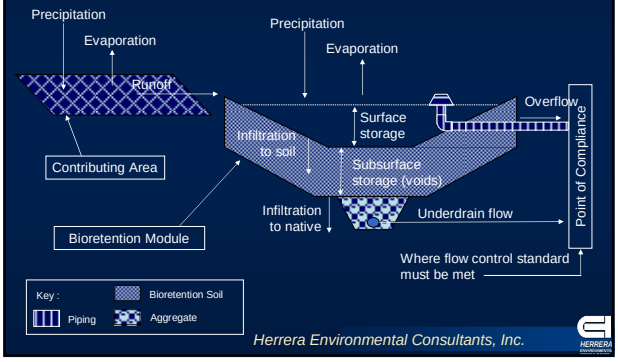
Model Configuration



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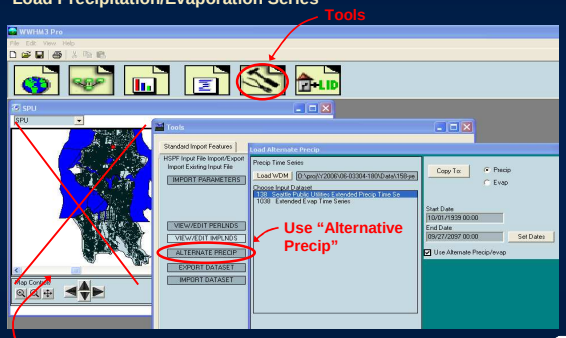
WWHM Example

Load Precipitation/Evaporation Series



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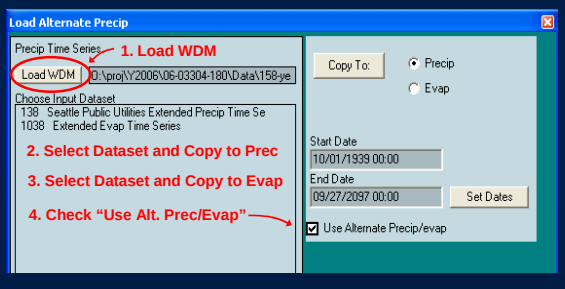
WWHM Example

Load Precipitation/Evaporation Series



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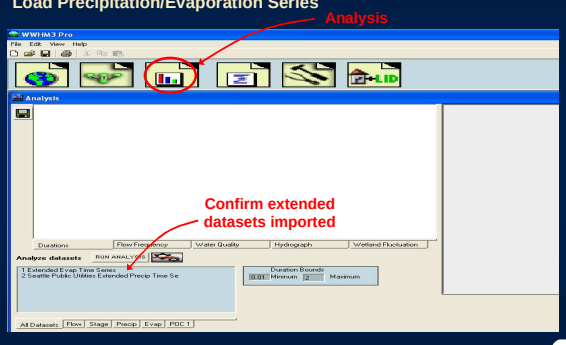
WWHM Example

Load Precipitation/Evaporation Series



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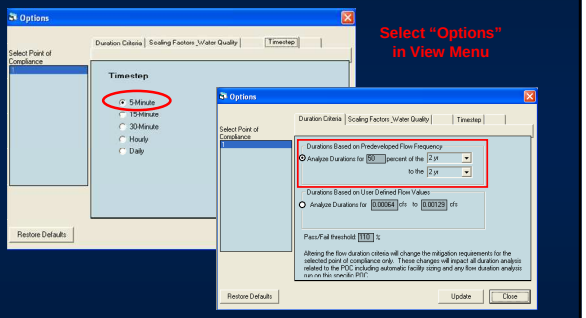
WWHM Example

Select 5 minute Time Step and Duration Range



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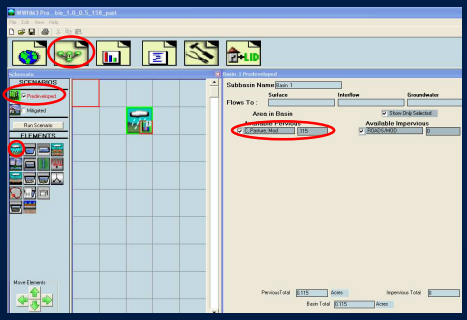
WWHM Example

Predeveloped Basin → Select area, soil type, land cover and slope



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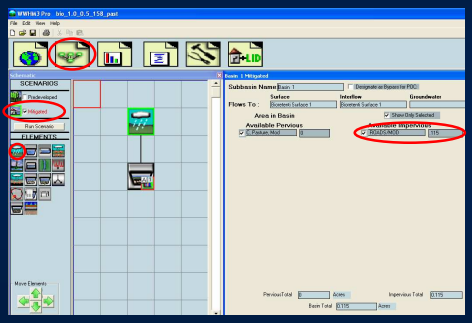
WWHM Example

Developed Mitigated Basin → Impervious with same area and slope



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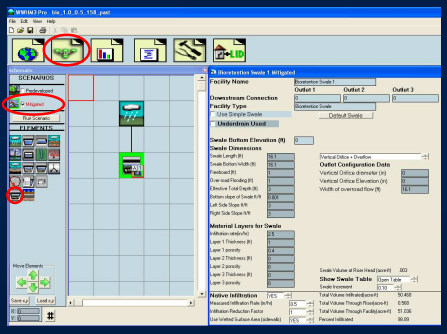
WWHM Example

Developed Mitigated Basin → Route to BMP



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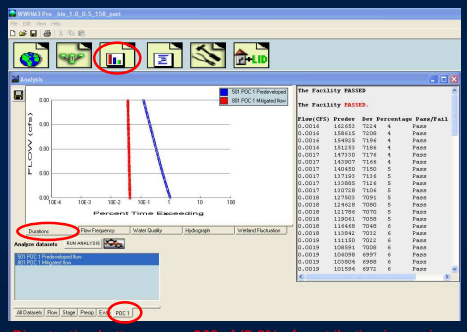
WWHM Example

Duration Curve Results (iterative sizing)



Bioretention bottom area= 260 sf (5.2% of contributing impervious area)

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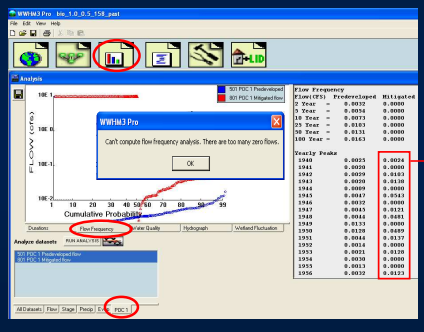
WWHM Example

Flow Frequency Results



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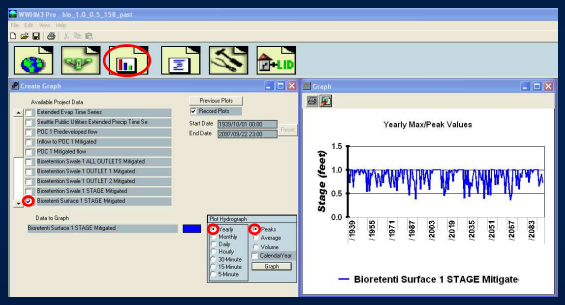
WWHM Example

Hydrograph



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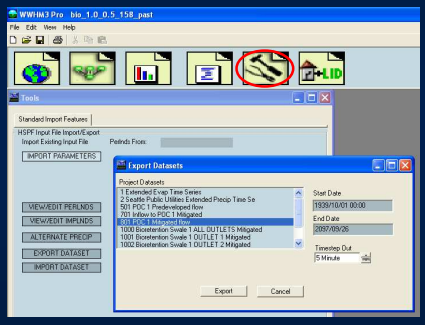
WWHM Example

Timeseries Export



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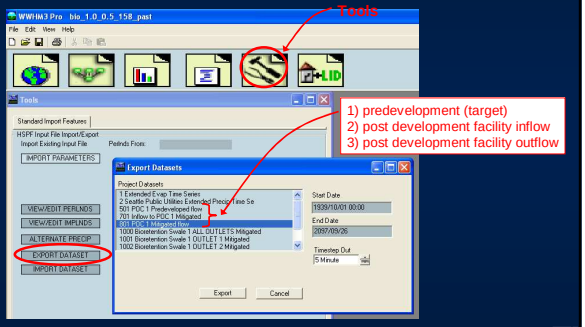
Hydrostats

Export Timeseries from WWHM



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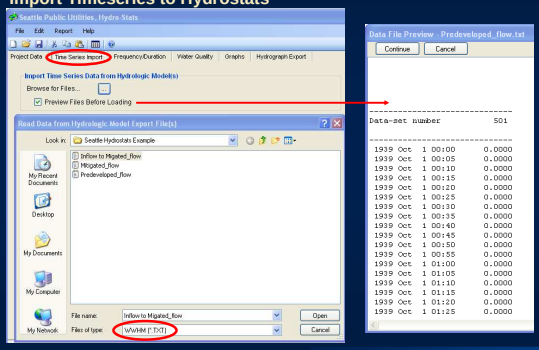
Hydrostats

Import Timeseries to Hydrostats



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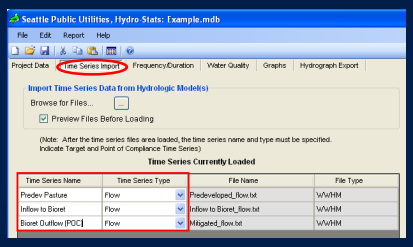
Hydrostats

Define Timeseries Type and Name



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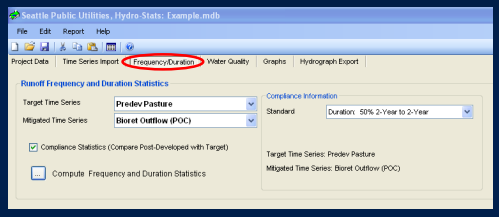
Hydrostats

Evaluate Flow Frequency and Duration



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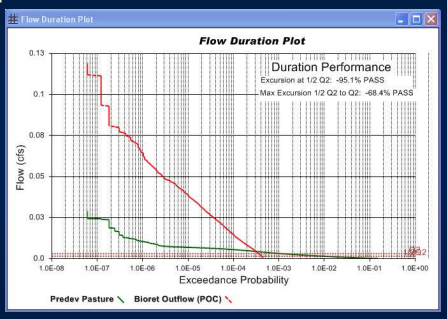
Hydrostats

Compliance Statistics



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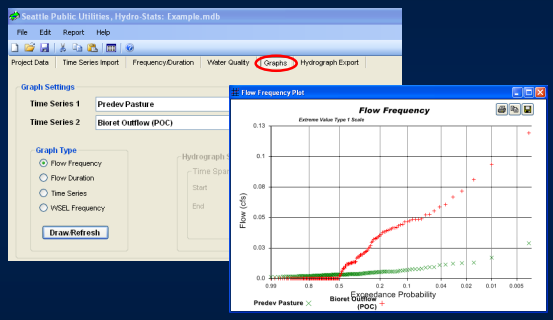
Compliance Statistics



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Hydrostats

Report

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Troubleshooting

- WWHM Bioretention→ "Freeboard"= ponding
- WWHM Bioretention → Takes 80 min to run
- WWHM Permeable Pvmnt Facilities→ Use ave. subsurface ponding depth as aggregate depth
- WWHM Flood Frequency (peak flows) → Incorrect for infiltration facilities (use Hydrostats)
- Pre-sized BMPs sized using preliminary shorter precip series → with 158-yr series, pre-sized infiltration BMPs are somewhat conservative and detention BMPs sized for peak are smaller

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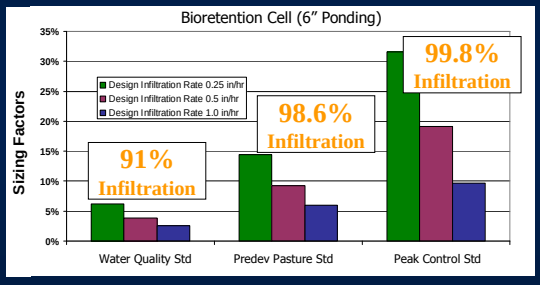
BMP Performance

Infiltration BMPs



Draft Sizing Factors

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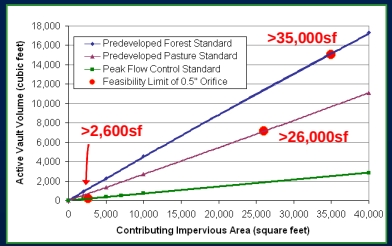
BMP Performance

Detention BMPs

Cannot achieve pasture or forest duration standard for smaller areas with minimum 0.5 inch orifice



3-foot diameter detention pipe

Note: 7,000 sf minimum for pasture standard with 0.25 inch orifice

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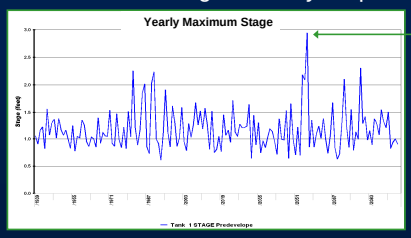
BMP Performance

Detention BMPs

- Maximize flow control benefit:
  Size 0.5" orifice and a 3-foot live storage depth for no overflows during the 158-year period



Note: Minimum contributing imp. area is 2,000sf

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Simplified Sizing Tool

- Small sites:<10,000 sf impervious area
- Pasture and Peak Stds
- Pre-designed BMPs
- Flow credits
  - Impervious reduction credit
- Sizing equations
  - BMP Size = f (Impervious Area & infiltration rate)
- Site design & BMP sizing without continuous modeling

BMP	Design Infilt. Rate (in/hr)	Sizing Factor
Bioretention Cell		
2 inch ponding depth	0.25	23.0%
	0.5	15.8%
	1.0	9.3%
6 inch ponding depth	0.25	14.6%
	0.5	9.9%
	1.0	6.4%
12 inch ponding depth	0.25	8.9%
	0.5	6.5%
	1.0	4.1%

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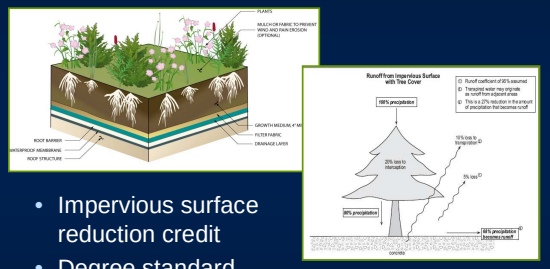
Flow Control Credits



- Impervious surface reduction credit
- Degree standard achieved

Seattle Public Utilities

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Flow Control Credit BMPs

- Retained Trees
- Newly Planted Trees
- Green Roof
- Dispersion
- Permeable Pavement Surface

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Flow Control Credit Design

- Retained Trees → – Evergreen and deciduous trees; – Minimum 6" DBH
- Newly Planted Trees
- Green Roof
- Dispersion
- Permeable Pavement Surface

Literature review of infiltration, evapotranspiration, interception

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Flow Control Credit Design

- Retained Trees
- Newly Planted Trees
- Green Roof → – 4" single-course; – 4" multi-course; – 8" multi-course
- Dispersion
- Permeable Pavement Surface

Performance modeled (EcoRoof)

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Flow Control Credits

Facility Type	Design Variable	Flow Control Credit	
		Pasture Standard	Peak Standard
Retained Trees	Evergreen	20% canopy area (min 100 sf/tree)	
	Deciduous	10% canopy area (min 50 sf/tree)	
New Trees	Evergreen	50 sf / tree	
	Deciduous	20 sf / tree	
Green Roof	4 inch depth	46%	71%
	8 inch depth	54%	79%
Dispersion	NA	90%	100%
Permeable Pavement Surface (3" subbase)	Slope ≤ 2%	100%	100%
	Slope 2% - 5%	45%	70%

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	Slope 2% - 5%	45%	70%

Impervious Area Mitigated = Canopy Area x 20%

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Permeable Pavement Surface (3" subbase)	Slope ≤ 2%	100%	100%
	Slope 2% - 5%	45%	70%

Impervious Area Mitigated = Green Roof Area x 71%
Downstream BMP Sized for Green Roof Area x 29%

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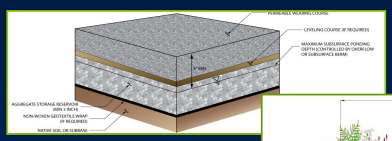
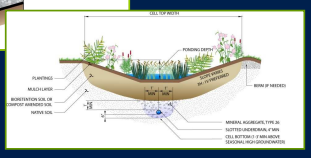
Sizing Factors





- Infiltration BMPs
- Sized to achieve FC & WQ stds
- Function of contributing area and infiltration rate

Seattle Public Utilities

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Sizing Factor BMPs

- Bioretention Cell
- Permeable Pavement Facility
- Bioretention Planter
- Infiltration Trench
- Drywell

Sizing Factor Design

- Bioretention Cell → –No underdrain; –Ponding: 2, 6 or 12”; –Side slopes 3H:1V; –12” bioretention soil (18” for treatment) per Seattle specs
- Permeable Pavement Facility
- Bioretention Planter
- Infiltration Trench
- Drywell

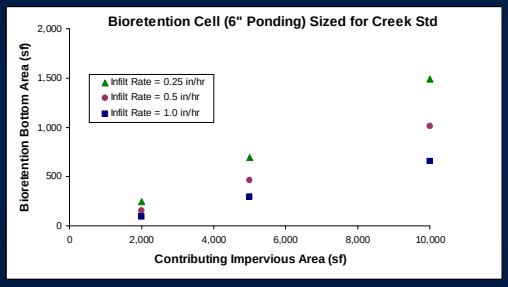
Sizing Factor Design

- Bioretention Cell
- Permeable Pavement Facility
- Bioretention Planter
- Infiltration Trench → –Aggregate depth: 1.5 or 3’
- Drywell

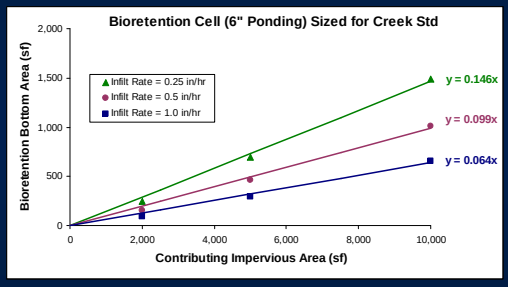
Sizing Factor Development

- Continuous Modeling Methods
  - WWHM3Pro
  - Glacial Till (hydrologic group C)/Mod. Slope
  - 5 minute time step
  - Contributing Imp Area: 2,000 – 10,000 sf
  - Design Infilt. Rates: 0.25, 0.5 and 1.0 in/hr
- Developed Relationship
  - Contributing Imp Area and BMP Area
  - Linear, typical R^2 ~0.99

Sizing Factor Development



Sizing Factor Development



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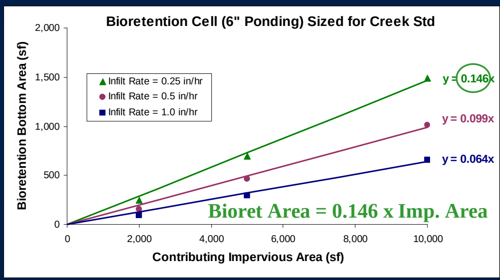

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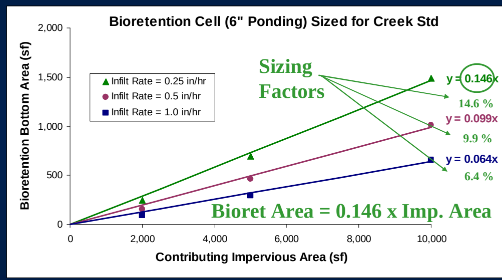
Sizing Factor Development



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Sizing Factors- Bioretention

BMP	Design Infilt. Rate (in/hr)	Pasture Standard	Peak Standard	Treatment Standard
Bioretention Cell				
2 inch ponding depth	0.25	23.0%	--	--
	0.5	15.8%	--	--
	1.0	9.3%	--	--
6 inch ponding depth	0.25	14.6%	33.1%	5.0%
	0.5	9.9%	20.5%	2.9%
	1.0	6.4%	10.6%	1.6%
12 inch ponding depth	0.25	8.9%	19.3%	3.0%
	0.5	6.5%	13.4%	1.7%
	1.0	4.1%	6.7%	0.9%

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Sizing Factors- Bioretention

BMP	Design Infilt. Rate (in/hr)	Pasture Standard	Peak Standard	Treatment Standard
Bioretention Cell				
2 inch ponding depth	0.25	23.0%	--	--
	0.5	15.8%	--	--
	1.0	9.3%	--	--
6 inch ponding depth	0.25	14.6%	33.1%	5.0%
	0.5	9.9%	20.5%	2.9%
	1.0	6.4%	10.6%	1.6%
12 inch ponding depth	0.25	8.9%	19.3%	3.0%
	0.5	6.5%	13.4%	1.7%
	1.0	4.1%	6.7%	0.9%

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	0.5	15.8%	--	--
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6 inch ponding depth	0.25	14.6%	33.1%	5.0%
	0.5	9.9%	20.5%	2.9%
	1.0	6.4%	10.6%	1.6%
12 inch ponding depth	0.25	8.9%	19.3%	3.0%
	0.5	6.5%	13.4%	1.7%
	1.0	4.1%	6.7%	0.9%

Bioretention Bottom Area = Contributing Impervious Area x 8.9%

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Sizing Factors- Bioretention

BMP	Design Infilt. Rate (in/hr)	Pasture Standard	Peak Standard	Treatment Standard
Bioretention Cell				
2 inch ponding depth	0.25	23.0%	--	--
	0.5	15.8%	--	--
	1.0	9.3%	--	--
6 inch ponding depth	0.25	14.6%	33.1%	5.0%
	0.5	9.9%	20.5%	2.9%
	1.0	6.4%	10.6%	1.6%
12 inch ponding depth	0.25	8.9%	19.3%	3.0%
	0.5	6.5%	13.4%	1.7%
	1.0	4.1%	6.7%	0.9%

Bioretention Bottom Area = Contributing Impervious Area x 3.0%

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Sizing Factors- PP Facilities

BMP	Design Infilt. Rate (in/hr)	Pasture Standard	Peak Standard	Treatment Standard
Permeable Pavement Facility				
6 inch ponding depth	0.25	60.6%	131.4%	--
	0.5	34.5%	52.4%	--
	1.0	33.3%	33.3%	--
12 inch ponding depth	0.25	38.2%	75.8%	--
	0.5	33.3%	38.7%	--
	1.0	33.3%	33.3%	--
Bioretention Planter with Underdrain				
6 inch ponding	NA	NA	NA	2.6%
12 inch ponding	NA	NA	6.5%	2.0%

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Sizing Factors- PP Facilities

BMP	Design Infilt. Rate (in/hr)	Pasture Standard	Peak Standard	Treatment Standard
Permeable Pavement Facility				
6 inch ponding depth	0.25	60.6%	131.4%	--
	0.5	34.5%	52.4%	--
	1.0	33.3%	33.3%	--
12 inch ponding depth	0.25	38.2%	75.8%	--
	0.5	33.3%	38.7%	--
	1.0	33.3%	33.3%	--
Bioretention Planter with Underdrain				
6 inch ponding	NA	NA	NA	2.6%
12 inch ponding	NA	NA	6.5%	2.0%

Pavement Area = Contributing Impervious Area x 38.7%

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Sizing Factors- Tradtl. Infiltration

BMP	Design Infilt. Rate (in/hr)	Pasture Standard	Peak Standard	Treatment Standard
Infiltration Trench				
1.5 foot depth	0.25	27.3%	55.1%	12.7%
	0.5	16.8%	30.0%	8.3%
	1.0	10.7%	17.4%	5.3%
3.0 foot depth	0.25	17.0%	31.9%	8.6%
	0.5	12.0%	20.1%	5.9%
	1.0	7.8%	13.1%	4.0%
Dry Well				
4 foot depth	0.25	13.6%	24.9%	7.5%
	0.5	10.1%	17.6%	5.1%
	1.0	6.7%	11.1%	3.5%
6 foot depth	0.25	9.7%	17.5%	6.1%
	0.5	7.9%	13.2%	4.2%
	1.0	5.7%	8.9%	2.8%

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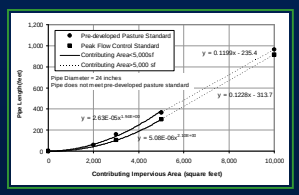
Sizing Factors- Tradtl. Detention

BMP	Contributing Area	Pasture Standard	Peak Standard
Detention Pipe			
24 inch diameter	< 5,000 sf	0.0000263A^1.9	0.00000508A^2.10
	5,000 – 10,000 sf	0.120A – 235	0.123A - 314
36 inch diameter	< 5,000 sf	0.000000219A^2.40	0.0000277A^2.05
	5,000 – 10,000 sf	0.0515A – 110	0.0546A- 167



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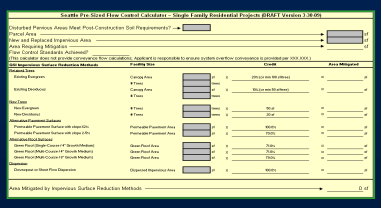
Sizing Calculator

- Guides designer through selecting and sizing BMPs
- Documentation for project submittal
- Includes MEF calculations



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